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Mapping distribution and thickness of supraglacial debris in the Central Karakoram National Park: main features and implications to model glacier meltwater

Umberto Minora (1), Christoph Mayer (2), Daniele Bocchiola (3), Carlo D'Agata (1), Davide Maragno (1), Astrid Lambrecht (2), Elisa Vuillermoz (4), claudio smiraglia (1), and guglielmina diolaiuti (1)

(1) Italy (umberto.minora@unimi.it), (2) Germany (Christoph.Mayer@lrz.badw-muenchen.de), (3) Italy (daniele.bocchiola@polimi.it), (4) Italy (elisa.vuillermoz@evk2cnr.org)

Supraglacial debris plays a not negligible role in controlling magnitude and rates of buried ice melt (Østrem, 1959; Mattson et al., 1993). Knowledge on rock debris is essential to model ice melt (and consequently meltwater discharge) upon wide glacierized areas, as melt rates are mainly driven by debris thickness variability. This is particularly important for the Pamir-Himalaya-Karakoram area (PHK), where debris-covered glaciers are frequent (Smiraglia et al., 2007; Scherler et al., 2011) and where melt water from glaciers supports agriculture and hydropower production.
By means of remote sensing techniques and field data, supraglacial debris can be detected, and then quantified in area and thickness. Supervised classifications of satellite imagery can be used to map debris on glaciers. They use different algorithms to cluster an image based on its pixel values, and Region Of Interests (ROIs) previously selected by the human operator. This can be used to obtain a supraglacial debris mask by which surface extension can be calculated. Moreover, kinetic surface temperature data derived from satellites (such as ASTER and Landsat), can be used to quantify debris thicknesses (Mihalcea et al., 2008). Ground Control Points (GCPs) are essential to validate the obtained debris thicknesses.
We took the Central Karakoram National Park (CKNP) as a representative sample for PHK area. The CKNP is 12,000 km2 wide, with more than 700 glaciers, mostly debris covered (Minora et al., 2013). Among those we find some of the widest glaciers of the World (e.g: Baltoro). To improve the knowledge on these glaciers and to better model their melt and water discharge we proceeded as follows. Firstly we ran a Supervised Maximum Likelihood (SML) classification on 2001 and 2010 Landsat images to detect debris presence and distribution. Secondly we analyzed kinetic surface temperature (from Landsat) to map debris depth. This latter attempt took also advantage from field data of debris thickness and surface rock temperatures acquired in the study area since the ablation season 2004 (see Mihalcea et al., 2006; 2008b). A mean debris thickness of ca. 5.6 cm was found, probably greater than the local "critical value" (sensu Mattson et al., 1993). Moreover, our field data indicate a local critical value of about 5 cm, above which supraglacial debris thickness would lower ice melt rates compared to that of bare ice (Mihalcea et al., 2006).
These findings suggest that in the CKNP area the abundant and extensive debris coverage may result in an actual reduction of buried ice melt. Moreover, Minora et al. (2013) reported quite stable conditions of glaciers in the CKNP area in the time window 2001-2011. This glacier behavior is consistent with the largely known "Karakoram Anomaly" (Hewitt, 2005) and requires further investigations. Among other possible important factors driving such a unique glacier trend, debris depth and distribution have to be considered.
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